WHAT IS CLAIMED IS:

1. An internal exhaust gas recirculation amount estimation system of an internal combustion engine comprising:

an exhaust valve closure timing in-cylinder temperature calculation section that calculates an in-cylinder temperature at an exhaust valve closure timing;

an exhaust valve closure timing in-cylinder pressure calculation section that calculates an in-cylinder pressure at the exhaust valve closure timing;

a gas constant calculation section that calculates a gas constant corresponding to a change in a composition of exhaust gas, based on an air-fuel mixture ratio;

an exhaust valve closure timing in-cylinder residual gas amount calculation section that calculates an in-cylinder residual gas amount at the exhaust valve closure timing, based on at least the in-cylinder temperature, the in-cylinder pressure, and the gas constant;

an valve overlap period blow-back gas amount calculation section that calculates a valve overlap period blow-back gas amount defined as a quantity of gas flow from one of intake and exhaust ports via a combustion chamber to the other port during a valve overlap period during which both of intake and exhaust valves are open together, the gas flow being created by a pressure difference between the intake and exhaust ports; and

an internal EGR amount calculation section that calculates an internal exhaust gas recirculation amount based on the exhaust valve closure timing in-cylinder residual gas amount and the valve overlap period blow-back gas amount.

2. The internal exhaust gas recirculation amount estimation system as claimed in claim 1, wherein:

the internal exhaust gas recirculation amount is arithmetically calculated by adding the valve overlap period blow-back gas amount to the exhaust valve closure timing in-cylinder residual gas amount, from a predetermined physical expression MRES = MRESCYL + MRESOL, where MRES denotes the internal exhaust gas recirculation amount, MRESOL denotes the valve overlap period blow-back gas amount, and MRESCYL denotes the exhaust valve closure timing in-cylinder residual gas amount.

3. The internal exhaust gas recirculation amount estimation system as claimed in claim 2, wherein:

a value of the valve overlap period blow-back gas amount (MRESOL) is defined as a positive value when a gas flows from the exhaust port toward the combustion chamber and then blows from the combustion chamber back to the intake port during the valve overlap period, and the value of the valve overlap period blow-back gas amount is defined as a negative value when a gas flows from the intake port toward the combustion chamber and then blows from the combustion chamber through the exhaust port during the valve overlap period.

4. The internal exhaust gas recirculation amount estimation system as claimed in claim 1, wherein:

the exhaust valve closure timing in-cylinder residual gas amount calculation section comprises:

(a) an exhaust valve closure timing in-cylinder volumetric capacity calculation section that calculates an in-cylinder volumetric capacity at the exhaust valve closure timing;

(b) the exhaust valve closure timing in-cylinder temperature calculation section that calculates the in-cylinder temperature at the exhaust valve closure timing;

(c) the exhaust valve closure timing in-cylinder pressure calculation section that calculates the in-cylinder pressure at the exhaust valve closure timing; and

(d) the gas constant calculation section that calculates the gas constant corresponding to the change in the composition of exhaust gas, based on the air-fuel mixture ratio;

the exhaust valve closure timing in-cylinder residual gas amount calculation section calculates the exhaust valve closure timing in-cylinder residual gas amount, based on the in-cylinder volumetric capacity, the in-cylinder temperature, the in-cylinder pressure, and the gas constant.

5. The internal exhaust gas recirculation amount estimation system as claimed in claim 4, wherein:

the exhaust valve closure timing in-cylinder residual gas amount is arithmetically calculated based on the in-cylinder volumetric capacity, the in-cylinder temperature, the in-cylinder pressure, and the gas constant, from a predetermined physical expression MRESCYL = (PEVC×VEVC)/(REX×TEVC), where PEVC denotes the in-cylinder pressure, VEVC denotes the in-cylinder volumetric capacity, REX denotes the gas constant, and TEVC denotes the in-cylinder temperature.

6. The internal exhaust gas recirculation amount estimation system as claimed in claim 4, wherein:

the exhaust valve closure timing in-cylinder volumetric capacity calculation section geometrically determines the

in-cylinder volumetric capacity based on a position of a reciprocating piston at the exhaust valve closure timing.

7. The internal exhaust gas recirculation amount estimation system as claimed in claim 4, wherein:

in the internal combustion engine employing both a variable valve timing mechanism that variably adjusts at least the exhaust valve closure timing and a variable compression ratio mechanism that variably adjusts a compression ratio by changing at least one of a top dead center and a bottom dead center of a piston stroke characteristic of a reciprocating piston, the exhaust valve closure timing in-cylinder volumetric capacity calculation section calculates the in-cylinder volumetric capacity based on a variation of the exhaust valve closure timing and the variation of the compression ratio.

8. The internal exhaust gas recirculation amount estimation system as claimed in claim 1, wherein:

the gas constant calculation section calculates the gas constant corresponding to the change in the composition of exhaust gas, based on a target combustion equivalent ratio.

9. The internal exhaust gas recirculation amount estimation system as claimed in claim 1, wherein:

the valve overlap period blow-back gas amount calculation section comprises:

(a) the exhaust valve closure timing in-cylinder temperature calculation section that calculates the in-cylinder temperature at the exhaust valve closure timing;

(b) the exhaust valve closure timing in-cylinder pressure calculation section that calculates the in-cylinder pressure at the exhaust valve closure timing;

(c) the gas constant calculation section that calculates the gas constant corresponding to the change in the composition of exhaust gas, based on the air-fuel mixture ratio;

(d) an intake pressure calculation section that calculates an intake pressure;

(e) a gas ratio-of-specific-heat calculation section that calculates a ratio of specific heat of gas, corresponding to the change in the composition of gas flowing between the intake and exhaust ports via the combustion chamber during the valve overlap period;

(f) a valve overlap period integrated effective area calculation section that calculates a valve overlap period integrated effective area for an opening area of the intake valve and an opening area of the exhaust valve during the valve overlap period;

(g) an engine speed calculation section that calculates an engine speed; and

(h) a supercharging-and-choking phenomena determination section that determines the presence or absence of a supercharging phenomenon regarding the gas flow between the intake and exhaust ports via the combustion chamber during the valve overlap period, the gas flow being created by the pressure difference between the intake and exhaust ports, and the presence or absence of a choking phenomenon regarding the gas flow between the intake and exhaust ports via the combustion chamber during the valve overlap period;

the valve overlap period blow-back gas amount calculation section calculates the valve overlap period blow-back gas amount, based on the in-cylinder temperature, the in-cylinder pressure, the gas constant, the intake pressure, the ratio of specific heat, the valve overlap period integrated effective area, and the engine speed, and a

decision result of the supercharging-and-choking phenomena determination section.

10. The internal exhaust gas recirculation amount estimation system as claimed in claim 9, wherein:

the valve overlap period blow-back gas amount is calculated based on the engine speed, the valve overlap period integrated effective area, and a temporary valve overlap period blow-back gas amount determined based on the supercharging-and-choking phenomena decision result, from a predetermined expression:

$$MRESOL = (MRESOL_{tmp} \times ASUMOL \times 60)/(NRPM \times 360)$$

where $MRESOL_{tmp}$ denotes the temporary valve overlap period blow-back gas amount, ASUMOL denotes the valve overlap period integrated effective area, and NRPM denotes the engine speed.

11. The internal exhaust gas recirculation amount estimation system as claimed in claim 10, wherein:

the supercharging-and-choking phenomena determination section comprises an intake-pressure-to-exhaust-pressure ratio calculation section that calculates a pressure ratio of intake pressure to exhaust pressure, based on the intake pressure and the in-cylinder pressure from a predetermined expression PINBYEX=PIN/PEVC, where PINBYEX denotes the pressure ratio, PIN denotes the intake pressure, and PEVC denotes the in-cylinder pressure;

the supercharging-and-choking phenomena determination section determines that the supercharging phenomenon is present when the pressure ratio is greater than a predetermined threshold value, and determines that the supercharging phenomenon is absent when the pressure ratio is less than or equal to the predetermined threshold value;

the valve overlap period blow-back gas amount calculation section calculates the valve overlap period blow-back gas amount by using the ratio of specific heat of exhaust gas, corresponding to the change in the composition of exhaust gas, when the supercharging phenomenon is absent; and

the valve overlap period blow-back gas amount calculation section calculates the valve overlap period blow-back gas amount by using the ratio of specific heat of air-fuel mixture, corresponding to the change in the composition of air-fuel mixture, when the supercharging phenomenon is present.

12. The internal exhaust gas recirculation amount estimation system as claimed in claim 9, wherein:

the valve overlap period integrated effective area calculation section calculates a valve overlap based on an intake valve open timing and the exhaust valve closure timing, and calculates the valve overlap period integrated effective area based on the valve overlap.

13. The internal exhaust gas recirculation amount estimation system as claimed in claim 9, wherein:

the valve overlap period integrated effective area calculation section sets a smaller one of the opening area of the intake valve and the opening area of exhaust valve as an effective valve opening area, and calculates the valve overlap period integrated effective area as an integrated value of the smaller opening area per unit time from a point of time corresponding to a beginning-of-valve-overlap crank angle to a point of time corresponding to an end-of-valve-overlap crank angle.

14. The internal exhaust gas recirculation amount estimation system as claimed in claim 1, further comprising:

a variable valve timing mechanism enabling at least one of an intake valve open timing and the exhaust valve closure timing to be varied; and

a valve timing calculation section that estimates the valve timing based on a valve-timing variation adjusted by the variable valve timing mechanism and affected by a valve temperature change and a motion-transmitting valve-train component parts wear;

the valve timing calculation section comprising:

(a) a valve clearance estimation section that estimates a valve clearance; and

(b) a valve timing compensation section that compensates for the valve timing based on the valve clearance estimated.

15. The internal exhaust gas recirculation amount estimation system as claimed in claim 14, wherein:

the valve clearance estimation section comprises a valve temperature calculation section that calculates a valve temperature; and

the valve clearance estimation section estimates the valve clearance based on the valve temperature.

16. The internal exhaust gas recirculation amount estimation system as claimed in claim 15, wherein:

the valve temperature calculation section comprises an engine load calculation section that calculates an engine load; and

the valve clearance estimation section estimates the valve clearance based on the engine load.

17. The internal exhaust gas recirculation amount estimation system as claimed in claim 14, wherein:

the valve timing calculation section comprising:

(a) an exhaust valve clearance estimation section that estimates an exhaust valve clearance;

(b) an exhaust valve closure timing compensation section that compensates for the exhaust valve closure timing based on the exhaust valve clearance estimated;

(c) an intake valve clearance estimation section that estimates an intake valve clearance; and

(d) an intake valve open timing compensation section that compensates for the intake valve open timing based on the intake valve clearance estimated;

18. The internal exhaust gas recirculation amount estimation system as claimed in claim 14, wherein:

the valve timing compensation section comprises:

(a) a valve-timing real value calculation section that calculates a valve-timing real value based on a frequency of oscillatory seating motion of each of the intake and exhaust valves under a predetermined condition that the engine is conditioned in a valve timing detectable engine operating state suited to detect the valve-timing real value;

(b) a valve-timing estimate calculation section that calculates, under the predetermined condition, a valve-timing estimate of the valve timing compensated for based on the valve clearance estimated and temperature-compensated for based on a change in a valve temperature;

(c) a valve timing error calculation section that calculates a valve timing error between the valve-timing real value and the valve-timing estimate; and

(d) a wear dependent valve-timing-correction learned value calculation section that calculates a valve-timing-

correction learned value based on the valve timing error; and

wherein the valve timing is further compensated for based on the valve-timing-correction learned value.

19. The internal exhaust gas recirculation amount estimation system as claimed in claim 18, further comprising:

a knock sensor that detects the frequency of oscillatory seating motion of each of the intake and exhaust valves.

20. The internal exhaust gas recirculation amount estimation system as claimed in claim 11, wherein:

the supercharging-and-choking phenomena determination section comprises a choking-phenomenon decision threshold value calculation section that calculates a minimum choking-phenomenon decision threshold value SLCHOKEL and a maximum choking-phenomenon decision threshold value SLCHOKEH based on the ratio of specific heat of gas, from predetermined expressions:

$$SLCHOKEL = \{2/(SHEATR+1)\}^{\{SHEATR/(SHEATR-1)\}}$$

$$SLCHOKEH = \{2/(SHEATR+1)\}^{\{-SHEATR/(SHEATR-1)\}}$$

where SHEATR denotes the ratio of specific heat of exhaust gas, corresponding to the change in the composition of exhaust gas, obtained when the supercharging phenomenon is absent, and the ratio of specific heat of exhaust gas is replaced with the ratio of specific heat of air-fuel mixture, obtained when the supercharging phenomenon is present;

the supercharging-and-choking phenomena determination section determines that the choking phenomenon is present when either of a condition that the pressure ratio is less than the minimum choking-phenomenon decision threshold value SLCHOKEL and a condition that the pressure ratio is greater

than the maximum choking-phenomenon decision threshold value SLCHOKEH is satisfied, and determines that the choking phenomenon is absent when the pressure ratio is greater than or equal to the minimum choking-phenomenon decision threshold value SLCHOKEL and the pressure ratio is less than or equal to the maximum choking-phenomenon decision threshold value SLCHOKEH; and

the valve overlap period blow-back gas amount calculation section comprises an unsupercharged and unchoked state, valve overlap period blow-back gas amount calculation section that calculates an unsupercharged and unchoked state, temporary valve overlap period blow-back gas amount from a predetermined expression:

$$MRESOL_{tmp} = \sqrt{2} \times PEVC \times MRSOLD \times MRSOLP$$

where PEVC denotes the in-cylinder pressure, MRSOLD denotes a density term and MRSOLP denotes a pressure difference term, and the density term MRSOLD and the pressure difference term MRSOLP are represented by predetermined expressions:

$$MRSOLD = SQRT\{1/(REX \times TEVC)\}$$

$$MRSOLP = SQRT[SHEATR/(SHEATR-1) \times \{PINBYEX^{(2/SHEATR)} - PINBYEX^{((SHEATR+1)/SHEATR)}\}]$$

where REX denotes the gas constant, TEVC denotes the in-cylinder temperature, SQRT denotes a coefficient for the gas constant REX and the in-cylinder temperature TEVC, SHEATR denotes the ratio of specific heat, and PINBYEX denotes the pressure ratio.

21. The internal exhaust gas recirculation amount estimation system as claimed in claim 20, wherein:

the valve overlap period blow-back gas amount calculation section comprises an unsupercharged and choked state, valve overlap period blow-back gas amount calculation section that calculates an unsupercharged and choked state, temporary

valve overlap period blow-back gas amount from a predetermined expression:

$$MRESOL_{tmp} = PEVC \times MRSOLD \times MRSOLPC$$

where PEVC denotes the in-cylinder pressure, MRSOLD denotes the density term and MRSOLPC denotes a pressure difference term, and the density term MRSOLD and the pressure difference term MRSOLPC are represented by predetermined expressions:

$$MRSOLD = SQRT\{1/(REX \times TEVC)\}$$

$$MRSOLPC = SQRT[SHEATR \times \{2/(SHEATR+1)\}^{\{(SHEATR+1)/(SHEATR-1)\}}]$$

where REX denotes the gas constant, TEVC denotes the in-cylinder temperature, SQRT denotes the coefficient for the gas constant REX and the in-cylinder temperature TEVC, and SHEATR denotes the ratio of specific heat.

22. The internal exhaust gas recirculation amount estimation system as claimed in claim 21, wherein:

the valve overlap period blow-back gas amount calculation section comprises a supercharged and unchoked state, valve overlap period blow-back gas amount calculation section that calculates a supercharged and unchoked state, temporary valve overlap period blow-back gas amount from a predetermined expression:

$$MRESOL_{tmp} = -\sqrt{2} \times \sqrt{\frac{1}{RIN \times TIN}} \times PIN \times MRSOLPT$$

where PIN denotes the intake pressure, RIN denotes a gas constant of intake air, TIN denotes a Kelvin absolute temperature of the intake air, and MRSOLPT denotes a pressure difference term represented by a predetermined expression:

$$MRSOLPT = SQRT[SHEATR/(SHEATR-1) \times \{PINBYEX^{(-2/SHEATR)} - PINBYEX^{(-(SHEATR+1)/SHEATR)}\}]$$

where SQRT denotes the coefficient, SHEATR denotes the ratio of specific heat, and PINBYEX denotes the pressure ratio.

23. The internal exhaust gas recirculation amount estimation system as claimed in claim 22, wherein:

the valve overlap period blow-back gas amount calculation section comprises a supercharged and choked state, valve overlap period blow-back gas amount calculation section that calculates a supercharged and choked state, temporary valve overlap period blow-back gas amount from a predetermined expression:

$$MRESOL_{tmp} = -\sqrt{\frac{1}{RIN \times TIN}} \times PIN \times MRSOLPC$$

where PIN denotes the intake pressure, RIN denotes the gas constant of the intake air, TIN denotes the Kelvin absolute temperature of the intake air, and MRSOLPC denotes a pressure difference term represented by the predetermined expression:

$$MRSOLPC = SQRT[SHEATR \times \{2/(SHEATR+1)\}^{\{(SHEATR+1)/(SHEATR-1)\}}]$$

where SQRT denotes the coefficient and SHEATR denotes the ratio of specific heat.

24. An internal exhaust gas recirculation amount estimation system of an internal combustion engine comprising:

exhaust valve closure timing in-cylinder temperature calculation means for calculating an in-cylinder temperature at an exhaust valve closure timing;

exhaust valve closure timing in-cylinder pressure calculation means for calculating an in-cylinder pressure at the exhaust valve closure timing;

gas constant calculation means for calculating a gas constant corresponding to a change in a composition of exhaust gas, based on an air-fuel mixture ratio;

exhaust valve closure timing in-cylinder residual gas amount calculation means for calculating an in-cylinder residual gas amount at the exhaust valve closure timing, based on at least the in-cylinder temperature, the in-cylinder pressure, and the gas constant;

valve overlap period blow-back gas amount calculation means for calculating a valve overlap period blow-back gas amount defined as a quantity of gas flow from one of intake and exhaust ports via a combustion chamber to the other port during a valve overlap period during which both of intake and exhaust valves are open together, the gas flow being created by a pressure difference between the intake and exhaust ports; and

internal EGR amount calculation means for calculating an internal exhaust gas recirculation amount based on the exhaust valve closure timing in-cylinder residual gas amount and the valve overlap period blow-back gas amount.

25. A method of estimating an internal exhaust gas recirculation amount of an internal combustion engine enabling the internal exhaust gas recirculation amount to be varied by changing a valve overlap, the method comprising:

calculating an in-cylinder temperature at an exhaust valve closure timing based on an exhaust temperature;

calculating an in-cylinder pressure at the exhaust valve closure timing based on an exhaust pressure;

calculating a gas constant corresponding to a change in a composition of exhaust gas, based on an air-fuel mixture ratio;

calculating an in-cylinder residual gas amount at the exhaust valve closure timing, based on at least the in-cylinder temperature, the in-cylinder pressure, and the gas constant;

detecting an engine speed;

calculating a valve overlap period integrated effective area for an opening area of the intake valve and an opening area of the exhaust valve during the valve overlap period;

determining the presence or absence of a supercharging phenomenon regarding the gas flow between the intake and exhaust ports via the combustion chamber during the valve overlap period, the gas flow being created by the pressure difference between the intake and exhaust ports, and the presence or absence of a choking phenomenon regarding the gas flow between the intake and exhaust ports via the combustion chamber during the valve overlap period;

calculating a valve overlap period blow-back gas amount, which is defined as a quantity of gas flow from one of intake and exhaust ports via a combustion chamber to the other port during a valve overlap period during which both of intake and exhaust valves are open together, and is based on the engine speed, the valve overlap period integrated effective area, and the supercharging-and-choking phenomena decision result regarding the presence or absence of the supercharging phenomenon, and the presence or absence of the choking phenomenon; and

calculating the internal exhaust gas recirculation amount by adding the valve overlap period blow-back gas amount to the exhaust valve closure timing in-cylinder residual gas amount.

26. The method as claimed in claim 25, wherein:

the valve overlap period integrated effective area is calculated based on the valve overlap.

27. The method as claimed in claim 25, wherein:

the valve overlap period integrated effective area is calculated by integrating an effective opening area per unit time from a point of time corresponding to a beginning-of-valve-overlap crank angle to a point of time corresponding to an end-of-valve-overlap crank angle, the effective opening area being set to a smaller one of the opening area of the intake valve and the opening area of exhaust valve.

28. The method as claimed in claim 25, wherein:

the valve overlap period blow-back gas amount is calculated based on the engine speed, the valve overlap period integrated effective area, and a temporary valve overlap period blow-back gas amount determined based on the supercharging-and-choking phenomena decision result, from a predetermined expression:

$$MRESOL = (MRESOL_{tmp} \times ASUMOL \times 60)/(NRPM \times 360)$$

where $MRESOL_{tmp}$ denotes the temporary valve overlap period blow-back gas amount, ASUMOL denotes the valve overlap period integrated effective area, and NRPM denotes the engine speed.

29. The method as claimed in claim 28, wherein:

an unsupercharged and unchoked state, temporary valve overlap period blow-back gas amount is calculated from a predetermined expression:

$$MRESOL_{tmp} = \sqrt{2} \times PEVC \times MRSOLD \times MRSOLP$$

where PEVC denotes the in-cylinder pressure, MRSOLD denotes a density term and MRSOLP denotes a pressure difference term, and the density term MRSOLD and the pressure difference term MRSOLP are represented by predetermined expressions:

$$MRSOLD = SQRT\{1/(REX \times TEVC)\}$$

$$MRSOLP = SQRT[SHEATR/(SHEATR-1) \times \{PINBYEX^{(2/SHEATR)} - PINBYEX^{((SHEATR+1)/SHEATR)}\}]$$

where REX denotes the gas constant, TEVC denotes the in-cylinder temperature, SQRT denotes a coefficient for the gas constant REX and the in-cylinder temperature TEVC, SHEATR denotes a ratio of specific heat of exhaust gas, corresponding to a change in a composition of exhaust gas, obtained when the supercharging phenomenon is absent, and the ratio of specific heat of exhaust gas is replaced with a ratio of specific heat of air-fuel mixture, obtained when the supercharging phenomenon is present, and PINBYEX denotes a pressure ratio of intake pressure to exhaust pressure.

30. The method as claimed in claim 29, wherein:

an unsupercharged and choked state, temporary valve overlap period blow-back gas amount is calculated from a predetermined expression:

$$MRESOL_{tmp} = PEVC \times MRSOLD \times MRSOLPC$$

where PEVC denotes the in-cylinder pressure, MRSOLD denotes the density term and MRSOLPC denotes a pressure difference term, and the density term MRSOLD and the pressure difference term MRSOLPC are represented by predetermined expressions:

$$MRSOLD = SQRT\{1/(REX \times TEVC)\}$$

$$MRSOLPC = SQRT[SHEATR \times \{2/(SHEATR+1)\}^{\{(SHEATR+1)/(SHEATR-1)\}}]$$

where REX denotes the gas constant, TEVC denotes the in-cylinder temperature, SQRT denotes the coefficient for the gas constant REX and the in-cylinder temperature TEVC, and SHEATR denotes the ratio of specific heat.

31. The method as claimed in claim 30, wherein:

a supercharged and unchoked state, temporary valve overlap period blow-back gas amount is calculated from a predetermined expression:

$$MRESOL_{tmp} = -\sqrt{2} \times \sqrt{\frac{1}{RIN \times TIN}} \times PIN \times MRSOLPT$$

where PIN denotes the intake pressure, RIN denotes a gas constant of intake air, TIN denotes a Kelvin absolute temperature of the intake air, and MRSOLPT denotes a pressure difference term represented by a predetermined expression:

$$MRSOLPT = SQRT[SHEATR/(SHEATR-1) \times \{PINBYEX^{(-2/SHEATR)} - PINBYEX^{(-(SHEATR+1)/SHEATR)}\}]$$

where SQRT denotes the coefficient, SHEATR denotes the ratio of specific heat, and PINBYEX denotes the pressure ratio.

32. The method as claimed in claim 30, wherein:

a supercharged and choked state, temporary valve overlap period blow-back gas amount is calculated from a predetermined expression:

$$MRESOL_{tmp} = -\sqrt{\frac{1}{RIN \times TIN}} \times PIN \times MRSOLPC$$

where PIN denotes the intake pressure, RIN denotes the gas constant of the intake air, TIN denotes the Kelvin absolute temperature of the intake air, and MRSOLPC denotes a pressure difference term represented by the predetermined expression:

$$MRSOLPC = SQRT[SHEATR \times \{2/(SHEATR+1)\}^{\{(SHEATR+1)/(SHEATR-1)\}}]$$

where SQRT denotes the coefficient and SHEATR denotes the ratio of specific heat.